THE VEGETATIVE ANATOMY OF FREYCINETIA SUMATRANA Hemsl. AND F. RIGIDIFOLIA Hemsl. ALONG WITH THE COMPARATIVE STUDY OF SHOOT APEX ORGANIZATION IN F. RIGIDIFOLIA AND PANDANUS TECTORIUS Soland.

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SUMMARY: By the study of the comparative anatomy of *Freycinetia sumatrana* and *F. rigidifolia* the anatomical distinction between them is well established particularly on the basis of the type and degree of specialization of stomata, occurrence of silica bodies and other ergastic substances, nature of bundle sheaths, structure of the spines, shape of the keel, presence or absence of translucent layer of parenchyma next to the adaxial epidermis in the keel, continuous or discontinuous occurrence of assimilatory tissues, etc. The structure of the shoot apex and its organization in *F. rigidifolia* and that of *Pandanus tectorius* represents two contrasting types and level of organization in that the former is characterized by three distinct zones, a well stabilized two-layered distinct tunica, the presence of a cambium-like zone and a central mother-cell-zone while in the latter only two zones are present (mantle layers and central mother-cell-zone).

RÉSUMÉ : L'étude anatomique comparative des parties végétatives de *Freycinetia sumatrana* et *F. rigidifolia* met en évidence des différences très nettes entre les deux espèces, en particulier dans le type et le degré de spécialisation des stomates, la présence de corps siliceux, et autres substances ergastiques, la nature des gaines des faisceaux, la structure des épines, la forme de la carène, la présence ou l'absence d'une couche de parenchyme translucide près de l'épiderme adaxial du sillon médian, la présence de tissus assimilateurs continus ou non. *F. rigidifolia* et *Pandanus tectorius* montrent deux types différents et deux niveaux d'organisation dans la structure de l'apex de la tige : la première espèce est caractérisée par trois zones distinctes, une tunique stable composée de deux couches, une zone d'aspect cambial et une zone centrale de cellules-mères, tandis que la seconde espèce ne comporte que deux zones (des couches formant un manteau et la zone centrale de cellules-mères).

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INTRODUCTION

SOLEREDER & MEYER (1933) in their systematic anatomical treatment of the family *Pandanaceae* have dealt with only five species of *Freycinetia* out of a total of more than 160 species reported now by LIM & STONE (1971). TOMLINSON (1965) has described the stomatal structure of six

known and six unnamed species of this genus. NORTH & WILLIS (1970) have contributed a preliminary account on the anatomy of stem and leaf of *F. hombronii* followed by the anatomy of reproductive organs of six species of Solomon Islands. Nevertheless no attention is bestowed on the importance of the epidermal characteristics of these taxa by these authors. STONE (1968) has studied the anatomy of pedicels, stamens, fruits of certain species of *Freycinetia* and in the light of which he has prophesied that such studies when extended to the remaining species might become a profitable area for future investigation. Quite recently LIM & STONE (1971) in an attempt to find out the putative value of epidermal characteristics in relation to taxonomic grouping have established their values in six Malayan and eight non Malayan species of this genus. The vascular construction in the stems of certain species of *Freycinetia* has been recently published by ZIMMERMANN & al. (1974). The present *prodromus* based on two species (sect. *Auriculifoliæ* & *Hemsleyella*) which are supposed to be endemics to Andamans suggests a moral that further comparative anatomical studies of all the species of this genus may not fail to reveal enough number of anatomical data which may be useful in taxonomic works. Viewed also from another angle such a study becomes imperative and essential in the wake of the progress witnessed in the present decade by the publication of the systematic anatomy of several families of the Monocotyledons. As far as the vegetative anatomy of *F. rigidifolia* and *F. sumatrana* is concerned practically complete anatomical information is not available barring the brief information on the root of *F. sumatrana* (REINHARDT, 1885) and certain limited aspects of their foliar anatomy (LIM & STONE, 1971).

The structure of the shoot apex and its organization for the family as a whole is not known. The present work deals with such an aspect in the case of two taxa. In this connection *F. rigidifolia* and *Pandanus tectorius* (local common species) have been studied and compared with each other.

MATERIAL AND METHODS

Free hand and sledge microtomed sections were prepared, stained with safranin and fast green of the fresh materials of *F. sumatrana* (PCM 11798 A) which was fixed in FPA by the authors and those of *F. rigidifolia* were fixed and sent by Dᵣ N. P. BALA-KRISHNAN, Regional Botanist, Port Blair, Andamans. Permanent slides were prepared by following the customary methods. Preparation of epidermal peels was accomplished by scraping away of the unwanted mesophyll tissues with the help of the razor blades by using " Parazone " (METCALFE, 1960; GOVINDARAJALU, 1966). Laminal bits were cleared by using 5 % sodium hydroxide followed by the treatment with saturated solution of chloral hydrate (FOSTER, 1950). Tissues of stems and roots were macerated with Jeffrey's reagent. Serial sections of shoot apices were taken at a thickness of 10 μm. One set of sections was stained with a combination of safranin and Delafield's Haematoxylin and another with safranin and fast green. The characterization of vascular bundles and metaphloem is after CHEADLE & UHL (1948 a, b) and that of stomata is after TOM-LINSON (1965) and STONE (1970).

DESCRIPTIONS OF INDIVIDUAL SPECIES

Freycinetia sumatrana Hemsl.

LEAF. *Abaxial surface:* Costal and intercostal areas well delimited; intercostal cells variable, short, rectangular, squarrish and hexagonal (Pl. 1, E). Costal cells axially elongated, broad; cell walls moderately thick, smooth; end walls straight. Stomata (L. 43.2-59.4 μm; W. 39.6-43.2 μm), occurring in the intercostal areas, unspecialized and belonging to class I, tetracytic without papilla, suborbicular with angular sides (Pl. 1, H); neighbouring cells 6-8 in number. Epidermal cells frequently becoming subdivided and each one of them exceedingly thick-walled, encysting a single or 4-6 cubical crystals (crystarque cells) (Pl. 1, F). Spines (L. 348-406 μm), obliquely oriented upwards towards the apex, the cells of which axially elongated, thick-walled; spines multicellular, pointed, ultimately becoming 1-celled at apex, present at the margin and the midrib (Pl. 3, E).

Adaxial surface: Cells isodiametric, or slightly axially elongated (Pl. 1, D); cell walls sinuous, moderately thick-walled. Stomata see abaxial surface, occasionally present but the polar subsidiary cells slightly larger than those of the abaxial stomata (Pl. 2, B); stomata always circular unlike those of the abaxial surface. Crystarque cells absent. Adaxial intercostal and costal cells sometimes containing granular silica materials of different shapes and sizes occurring in discontinuous rows (Pl. 1, J; 2, G). Costal cells, see abaxial surface.

Lamina, transverse section: Outline flanged V-shaped (METCALFE & GREGORY, 1964; Pl. 1, C), symmetrical, isolateral with adaxial median groove. Cuticle moderately thick, smooth over both surfaces. Keel prominent, acutely triangular (Pl. 1, C). Adaxial epidermal cells variable, tabular; abaxial cells with convex surfaces in certain places and appearing papillate due to the superimposition with blunt cone-like silica-bodies (Pl. 2, I) or tabular throughout. Margins acute, slightly sloping downwards (Pl. 1, C). Stomata amphistomatic, somewhat sunken and possessing prominent outer ledges (Pl. 1, K); substomatal chamber rather broad and not associated with papillæ. Hypodermis consisting of ca. 3 layers of large colourless cells in the adaxial regions and ca. 2 layers in the abaxial regions (Pl. 1, A) but in the midrib region being replaced by a single layer of tangentially elongated thick-walled cells known as the translucent cells present on the adaxial side and 2-3 layers of similar cells present internally to abaxial surface (Pl. 1, C). Assimilatory tissue consisting of short, slightly elongated cells, adaxially 2-3-layered and abaxially 1 (-2)-layered (Pl. 1, A) and appearing continuous (Pl. 1, C). Air-cavities elongated, as many as and regularly alternating with vascular bundles, each one of them containing 3 layers of slightly lobed thin-walled colourless cells out of which the median layer consisting of larger cells (Pl. 1, A). Mesophyll

cells slightly lobed (Pl. 1, G). Bulliform cells occurring in 2-3 layers, each layer containing 10-11 cells arranged in more or less regular fan-shaped groups (METCALFE & GREGORY, 1964; Pl. 1, C). Vascular bundles 27 (13 + 1 + 13), oval (type IV; Pl. 1, B), all being similar and arranged at regular intervals; metaxylem vessel elements (D. 18-22 μm in diameter), circular; number of metaxylem vessel elements with respect to each vascular bundle variable, sometimes solitary (Pl. 4, E) or in groups of 2-3 (Pl. 1, B) and in either case protoxylem appearing separated from metaxylem or both of them juxtaposed. Septate fibers more commonly present. Metaphloem of ' irregular type ' but not easily distinguishable because of surrounding sclerenchyma; but when recognizable, it consisting of 6-8 thick-walled sieve tube elements. Bundle sheath single-layered, parenchymatous, irregular (Pl. 1, B; 4, E). Circumvascular sclerenchyma 8-10-layered, forming a deeply crescentiform cap at the phloem pole of each vascular bundle; some of its cells containing cubical crystals. Sclerenchyma strands variable (Ht. 12.6-21.6 μm; W. 14.4-46.8 μm) occurring solitarily or in groups of 2-5 cells, squarrish, hexagonal, rectangular or triangular and present next to abaxial and adaxial epidermis and sometimes within the hypodermis (Pl. 1, A; 2, H) and also in the midst of abaxial and adaxial assimilatory tissues: each cell characterized by concentric lamellations with narrow circular-oval lumina and some of the cells containing cone-shaped silica-body projecting into the lumina (Pl. 2, H). Idioblasts of three kinds present: a) raphide sacs present internal to adaxial palisade; the raphides being pencil-shaped (flat at one end and pointed at the other (Pl. 2, C); b) cells containing opaque more or less spherical, lobed, greyish black bodies bearing crystalline shining nodules present in the hypodermis and also within the adaxial assimilatory tissues (Pl. 2, D) and in the midst of colourless mesophyll cells (Pl. 2, L, M); c) smaller abaxial hypodermal cells containing cubical crystals common (Pl. 1, I).

SHEATH. *Abaxial surface:* Cuticle striated. Epidermal cells broader than long and arranged in more or less regular rows. Cell walls thin, sinuous; end walls straight or overlapping. Stomata (L. 58-60.9 μm; W. 25.8-28.7 μm), see leaf; interstomatal cells short with straight end walls. Crystal bearing idioblasts present at the junction of epidermal cells in certain places and occurring in discountinuous rows, each one of them bearing a single cubical crystal. Hypodermal fibers quite common occurring solitarily. Granular silica-bodies present in the distal cells of

Pl. 1. — **Freycinetia sumatrana :** A, T.S. lamina *p.p.* × 100; B, T.S. laminal vascular bundle × 150; C, T.S. lamina, ground plan × 30; D, surface view of adaxial epidermis of lamina × 200; E, surface view of abaxial epidermis of lamina × 200; F, crystarque cell from abaxial surface of lamina × 330; G, lobed mesophyll cells × 120; H, surface view of stoma from abaxial epidermis of lamina × 330; I, crystarque cell from abaxial hypodermis of lamina × 180; J, adaxial intercostal cells of lamina with silica materials × 270; K, T.S. of laminal stoma × 330. — **Pandanus tectorius :** L, T.S. shell zone × 200.
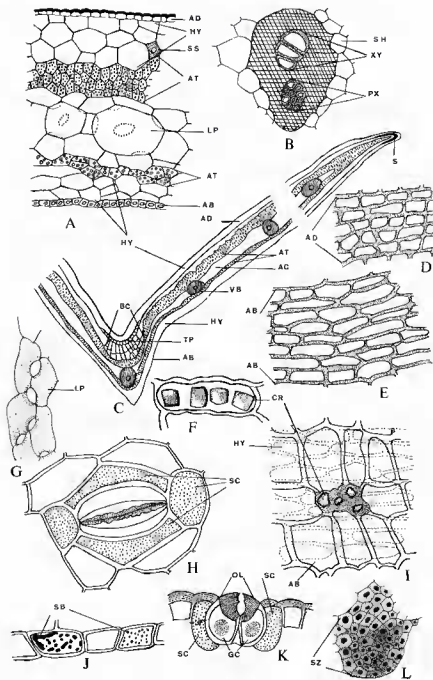
the sheath. Marginal spines (L. 464-522 µm), multicellular, multistratose, obliquely erect, pointed; cells short to moderately elongated, moderately thick-walled as in leaf (Pl. 3, E); those at the distal end (L. 696-812 µm) longer and curved.

Adaxial surface: Cells axially elongated, very narrow, thin-walled, smooth with straight or overlapping end walls. Crystal bearing idioblasts, see abaxial surface. Stomata (L. 43.5-46.5 µm; W. 26.1-29.0 µm), occasional, see leaf.

Transverse section: Outline shallow crescentiform. Cuticle moderately thick on either surface. Both adaxial and abaxial epidermal cells small, thick-walled, variable; abaxial epidermal cells raised, convex; adaxial cells tangentially elongated, tabular. Stomata unspecialized, belonging to class I. Hypodermis absent. Mesophyll of 3-4 layers of large hexagonal mostly colourless cells compactly arranged without intercellular spaces. Sclerenchyma represented in several units, each unit consisting of 1-4 cells in the midst of mesophyll tissue mostly solitarily or sometimes linearly arranged; cells rectangular or isodiametric characterized by lamellated thickenings (Pl. 5, D). Vascular bundles few and far between, circular in outline, belonging to type I. Circumvascular sclerenchyma either deeply crescentiform forming a cap at the phloem pole or almost surrounding the vascular bundles (Pl. 5, D). Raphide sacs less common (Pl. 4, D). Cubical crystals commonly present in the abaxial epidermal cells. Bundle sheath absent.

STEM. *Transverse section:* Diameter of the stem examined 1.7 cm. Outer surface protected by 6-10 layers of phelloid cells (Pl. 2, F) filled with tannin. Cortex: 20-25 layers of parenchyma consisting of cells variable in size and shape and arranged with intercellular spaces. Fiber bundles oval-elliptical in outline embedded in the cortex and occurring along with leaf trace bundles (Pl. 2, F); the peripheral cells of the fiber bundles containing cubical crystals. Leaf trace bundles 20-25 in number arranged in a ring, each one of them characterized by 2-3 layers of crescent-shaped sclerenchyma at the phloem side and the cells of which containing cubical crystals. Cells with greyish granular contents and also thick-walled cells

Pl. 2. — *Freyelnelia sumalrana* : A, metaxylem vessel member from stem × 80, *p.p.*; B, stoma from adaxial surface of lamina, surface view × 330; C, raphide sac from the adaxial assimilatory tissue, arrow indicates a single unit of the raphide × 330; D, lamina, hypodermal idioblast containing nodular body × 200; E, T.S. peripheral monopolar vascular bundle × 78; F, T.S. stem, ground plan × 13, *p.p.*; G, lamina, adaxial costal and intercostal cells with silica particles × 200; H, lamina, adaxial sclerenchyma strands with cone shaped silica-body × 200; I, lamina, abaxial epidermis with silica deposits × 200; J, T.S. thick-walled cortical cell of the stem with silica particles × 200; K, T.S. root, ground plan × 40; L, lamina, colourless mesophyll cell with greyish black body × 200; M, lamina, colourless mesophyll cell with greyish black body × 330.
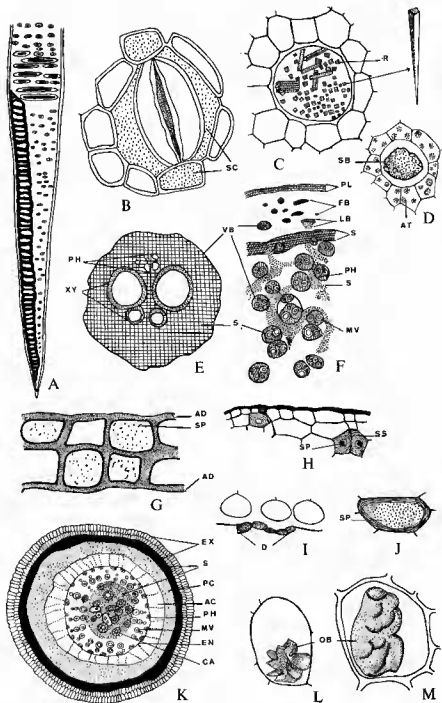
containing silica particles occasionally present in the cortex (Pl. 2, J). Cortex internally delimited by 10-12 layers of sclerenchyma (Pl. 2, F). Vascular bundles (type III A) many, scattered, suborbicular or oval in outline (Pl. 2, E, F). Bipolar vascular bundles as reported by TOMLINSON & ZIMMERMANN (1967) for the family, varying from 40-45 in number commonly repeated towards the centre of the axis (Pl. 5, E); rarely incomplete or partial bipolar vascular bundles (since each one of them possessing only one unit of metaphloem instead of two) also present in addition; those towards the periphery being monopolar (Pl. 2, E); the metaxylem elements sometimes occupied with multicellular tyloses which ultimately causing the obliteration in the outline of the vessel element itself (Pl. 5, C); metaxylem vessel members characterized by oblique end walls and scalariform perforation, the latter possessing 50-80 bars (Pl. 2, A); lateral walls provided with scalariform — opposite pittings (Pl. 2, A) and when exclusively opposite and crowded the outlines of the individual pit becoming flattened and angular (Pl. 5, B); vessel members (D. 0.13 mm in diameter) and having a mean length of 6.9 mm. Metaphloem of " irregular type ", each unit consisting of 4-7 large sieve tube elements with as many companion cells (Pl. 3, C), sometimes not easily distinguishable. Ground tissue in the cortex sclerenchymatous and parenchymatous towards the centre. Bundle sheath single, fibrous, complete in the case of central vascular bundles and not easily distinguishable in the peripheral bundles. Septate fibers occasionally present. Idioblasts: raphide sacs common in the cortex and the central parenchymatous part surrounding the vascular bundles.

ROOT. *Transverse section:* Diameter of the root examined 1.04 mm. Exodermis: 2-layered consisting of radially elongated large, thin-walled, hexagonal cells (Pl. 2, K). Cortex differentiated into 3 zones, the outer zone consisting of 23 layers of sclerenchyma, the middle 6-8 layers of large parenchyma cells arranged without intercellular spaces and the inner zone characterized by radially elongated air spaces, each one of them separated by radiating rows of parenchyma (Pl. 2, K). Endodermis not distinct but in certain places cells with uniform thickening present. Pericycle 1-layered, distinct, parenchymatous. Metaxylem and metaphloem units many, the former not only forming a perimedullary ring but also distributed in the medulla thus forming a central core of metaxylem elements (Pl. 2, K). Metaxylem vessel elements large (D. 36-45 μm in diameter), circular in outline; vessels with oblique end walls and scalariform
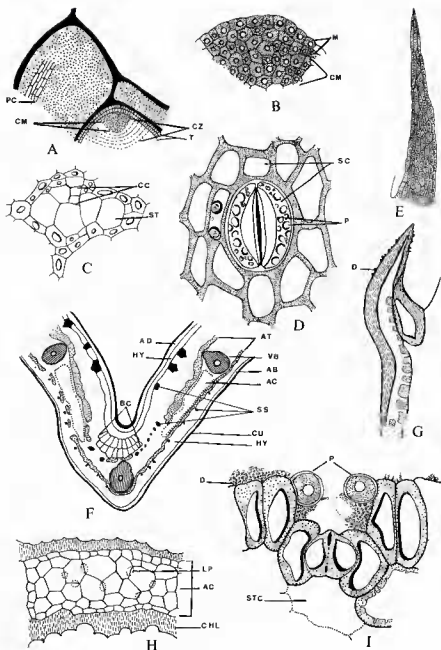
perforation, the latter bearing 15-30 bars; lateral wall pitting opposite. Metaphloem of " regular type " containing 3-4 large sieve tube elements with as many companion cells. Central ground tissue parenchymatous having large schizogenous secretory cavities (Pl. 2, K). Perimedullary vascular elements embedded in sclerenchyma.
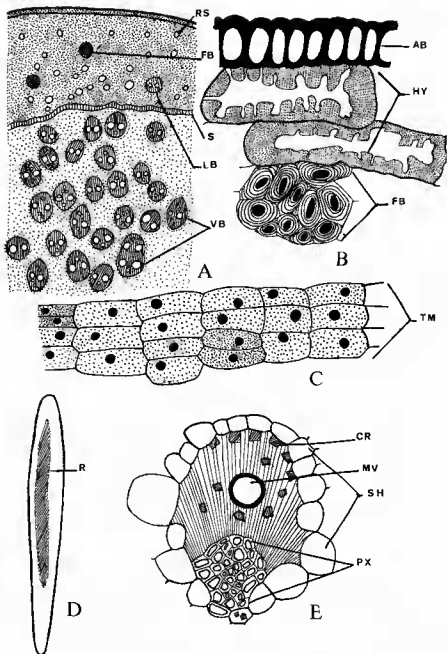
Freycinetia rigidifolia Hemsl.

LEAF. *Abaxial surface*: Cells isodiametric, smooth (not papillose). Stomata specialized belonging to class II and characterized by papillose subsidiary cells (Pl. 3, D); neighbouring cells 10-11 in number. Cells containing nodulose oval or elliptic silica-bodies abundantly present. Sometimes cells containing black granular materials also present. Other details, see *F. sumatrana*.

Lamina, transverse section: Keel obtusely triangular (Pl. 3, F). Substomatal chamber narrow. Abaxial and adaxial hypodermis 3-layered. Bulliform cells 2-layered, each layer containing 9 cells. Assimilatory tissue on the adaxial side of the midrib region broken by sclerenchymatous strands and thus becoming discontinuous (Pl. 3, F) and likewise becoming discontinuous throughout the abaxial side (Pl. 3, F). Translucent parenchyma absent in the midrib next to adaxial epidermis (Pl. 3, F). Aircavities relatively small in size possessing 4-5 layers of cells (Pl. 3, H). Bundle sheath complete. Circumvascular sclerenchyma 3-6-layered. Metaxylem vessel members broad (D. 27-31.5 μm in diameter). Raphide sacs absent. Sclerenchyma strands not containing silica-bodies. Other details as in *F. sumatrana*.

SHEATH. *Epidermis, surface view*: Abaxial cells axially elongated; cells walls thick, more or less smooth, pitted; end walls always straight. Marginal spines 1-or 2-celled, cell walls of which exceedingly thick, pitted (Pl. 3, G). Crystarque cells abundant in abaxial layers particularly towards the distal end of the spines occuring almost in a continuous row but absent in the adaxial layer. Other details, see *F. sumatrana*.

Transverse section: Abaxial epidermal cells radially elongated, papillate. Stomata amphistomatic, specialized belonging to class II (Pl. 3, I). Sclerenchyma strands (L. & W. 54 μm) well developed, variable (circular, triangular, squarrish, pulviniform and polygonal) occurring nearer to abaxial epidermis (Pl. 4, B). Hypodermis present (Pl. 4, B) the cells of which containing nodular silica-bodies. Bundle sheath 1-layered, parenchymatous, complete. Circumvascular sclerenchyma 2-layered and always present at the phloem pole. For other details, see *F. sumatrana*.

STEM. *Transverse section*: Outer phelloid layers absent (Pl. 4, A). Cortex relatively broad and internally delimited by a single layer of scleren-

Pl. 4. — **Freycinetia rigidifolia : A,** T.S. stem, ground plan × 23, *p.p.*; **B,** T.S. sheath, ground plan × 210, *p.p.* — **Pandanus tectorius : C,** T.S. primary thickening meristem × 210. — **F. sumatrana : D,** raphide sac from sheath × 140; **E,** T.S. laminal vascular bundle × 210.

chyma. Fiber bundles circular in outline. Leaf trace bundles 30-35 in number. Bundle sheaths distinct in all vascular bundles. Tyloses absent. Raphide sacs absent in the cortex. Other details as in *F. sumatrana*.

SHOOT APEX. — The apex (Ht. 220-150 µm; W. 240 µm) is dome-shaped exhibiting three distinct cytohistological zonation (Pl. 3, A) rather than conforming to a typical tunica-corpus type of organization (*sensu* SCHMIDT, 1924) because of the fact that the summit consists of a group of cells known as central mother-cells as reported by FOSTER (1938) in *Ginkgo biloba*. The cells of this zone are lightly stained and appear to be not only larger and more vacuolated than those that are present in the adjacent and subjacent regions with reference to the group of central mother-cells (Pl. 3, A, B). The height and width of the central mother-cell zone is ca. 60 µm and 90 µm respectively. The ratio between the cell size and the nuclear size is 1.5:1 and the cells within the group appear to be isodiametric and angular in outline (Pl. 3, B). However the contour of the central mother cell zone appears to be broadly V-shaped (Pl. 3, A),

The tunica is 2-layered and seems to be well stabilized consisting of somewhat radially elongated cells (L. ca. 9 µm; W. ca. 9 µm; Pl. 3, A) and the nucleus having a diameter of ca. 4.5 µm. Although the tunica is supposed to be theoretically continuous over the summit there appears to be a break in its continuity at the summit because its cells look more like those of the central mother-cell zone in cytohistological features and stainability than those that are present in the rest of the tunica layers. In other words, it appears as though the central mother-cells have encroached upon the tunica situated at the summit and merged with the latter (Pl. 3, A). When compared with the cytohistological features of the central mother-cells the tunica cells are more densely cytoplasmic and less vacuolated showing greater avidity for staining.

Beneath the group of central mother-cells there is a cup-or bowl-shaped cambium-like zone made up of 5-6 layers of cells extending laterally and joining with the tunica layers (Pl. 3, A). The individual cells of these layers (L. ca. 12 µm; W. ca. 6 µm) is tangentially flattened and the nucleus has a diameter of ca. 4.5 µm. Besides the above mentioned 3 zones no other zone such as flank meristem, rib meristem etc. could be recognized in this species.

Axillary buds are well developed in the axils of all the leaves but remain in a dormant condition. Subtending each axillary bud there is a well differentiated shell zone as in *Pandanus tectorius* (Pl. 1, L). The activity of primary thickening meristem is easily observed just beneath the leaf though not conspicuous and continuous. A little distance away from the cambium like zone quite a number of procambial strands differentiate and get oriented in different directions. Raphide idioblasts although common but restricted mostly to the peripheral parts of shoot apex. No cubical crystals are present.
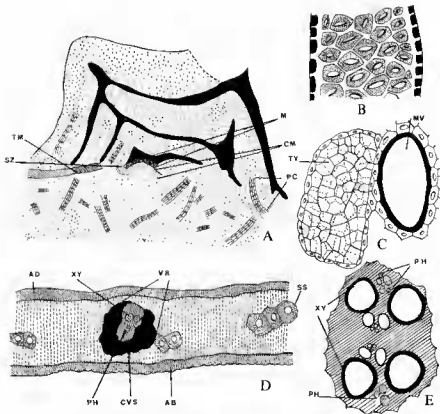
Pl. 5. — **Pandanus tectorius** : A, L.S. shoot apex, ground plan × 50. — **Freycinetia sumatrana** :
B, surface view of metaxylem vessel member showing lateral wall pitting × 50; C, T.S.
metaxylem vessel member with and without tylose × 330; D, T.S. sheath ground plan
330, *p.p.*; E, T.S. bipolar vascular bundle of stem × 130.

Pandanus tectorius Sol.

SHOOT APEX. — The apex as shown in Pl. 5, A is dome-shaped having
a diameter of 209 μm and a height of 93 μm. As the number of layers
and the planes of cell division in the extreme distal zone are so variable in
different loci, the application of the term " mantle layers " (POPHAM &
CHAN, 1950) is better suited than the adoption of the term tunica layers
(SCHMIDT, 1924). The number of mantle layers as far as this species is
concerned ranges from 2-3. The cells comprising the mantle layers are
all similar with respect to cytohistological features and stainability and
thus appears to be continuous over the summit unlike the situation observed
in *F. rigidifolia* (compare Pl. 3, A and 5, A). Just behind the mantle

layers a central mother-cell zone is present and this is as broad as the mantle layers (Pl. 5, A). Besides these two zones no other zone worthy of its name could be discovered from the structural, cytohistological and functional standpoints. However, the cells situated behind the central mother-cell zone are all more or less isodiametric and at the same time larger than those of the previous zone. Furthermore, the cells are also characterized by high degree of vacuolation. On the other hand, the few layers of cells that are situated behind and subjacent to the leaf primordia are compactly arranged, tiered and tangentially flattened (Pl. 4, C) and show periclinal division activity. This layer of periclinally dividing cells is identified as the primary fractionating meristem which is well demarcated and forming more or less continuous layers unlike those of *F. rigidifolia*, and this meristematic layer is analogous to that of palms (BALL, 1941; TOMLINSON, 1961). Each leaf primordium subtends a distinct axillary bud but the cells of which possess deeply stainable contents. The axillary buds are all subtended by well differentiated shell zones (Pl. 1, L). Raphide containing idioblasts and cubical crystals, see *F. rigidifolia*.

DISCUSSION

At present it is gratifying to note that the taxonomic and anatomical investigations focussed on this interesting family by St JOHN (1960 *et seq.*), KAM (1969), KAM & STONE (1970), STONE (1968), SZE PENG CHU & STONE (1973), TOMLINSON (1965), ZIMMERMANN & al. (1974) and a few others seem to gravitate towards wiping out the erstwhile stigma regarding the backward state of knowledge of this family and thus it may be hoped that such a cumulative data may ultimately engender undoubtedly the establishment of a microdiscipline known as " Pandanology " particularly in view of the large size of the family.

As mentioned earlier the general vegetative anatomical information on the family as a whole is not only meagre but even less so from systematic standpoint. It becomes clear on scanning through literature that even today this kind of lacuna has not yet been bridged up completely although beginnings have already been made by few authors pertaining to certain taxa selected at random (TOMLINSON, 1965; KAM, 1969; KAM & STONE, 1970; NORTH & WILLIS, 1970; LIM & STONE, 1971; SZE PENG CHU & STONE, 1973; ZIMMERMANN & al., 1974). The investigations of six Malayan and eight non Malayan species belonging to nine sections of *Freycinetia* have thrown some light on the existence of anatomical variability among them and on the basis of which LIM & STONE (1971) were able to propose anatomical key despite the contrary opinion to the effect that the gamut of variation in the foliar anatomy of *Freycinetia* is much narrower than what is available in *Pandanus* (TOMLINSON, 1965; NORTH & WILLIS, 1970). When the pilot study of LIM & STONE (1971) based upon only certain aspects of foliar anatomy such as stomatal structure, presence or absence of intercostal differentiation in the abaxial epidermis, shape and size of epidermal

cells, presence or absence of epidermal papillæ and their distribution, number of associated neighbouring cells of the stomata, the presence or absence of silica-bodies and their abundance and distribution when present has not failed to indicate their potential values at the sectional and sometimes even at the species level, the utilization of many more and diverse kinds of anatomical characteristics of the lamina, sheaths, stems and roots as pursued here may ultimately yield many more useful data and dicta for the internal classification, fixing up interrelationships and solving the taxonomic problems in *Freycinetia*. This assumption is engendered and encouraged by the results of the present complete anatomical studies of the two species. To name a few important anatomical characters by which these two taxa can be distinguished are observed with respect to the shape of the keel, number of hypodermal layers, presence or absence of silica-bodies, type of bundle sheaths, number of layers in circumvascular sclerenchyma, number of bulliform cells and their layers, the size and shape of sclerendyma strands and the pattern of distribution, presence or absence of raphide sacs, number of assimilatory tissues, number of cell layers in the air cavities, type of stomata, morphology of the costal and intercostal cells. Therefore it may be presumed in the light of the present work that future studies when pursued along these lines covering all the species on a comparative basis may yield anatomical data and micromorphological dicta of taxonomic importance.

Although there is a perfect agreement between our observations and those of LIM & STONE (1971), the following discrepancies have been noticed which perhaps may be attributed to the anatomical variability of these characters. For example LIM & STONE (1971) have reported the occurrence of specialized stomata in *F. sumatrana* and *F. rigidifolia* which the present authors are able to observe only in the latter. It is also stated by them that the silica-bodies are solitary or in pairs in *F. sumatrana* but as far as our observations go they are present not only in the form of granular materials but also the cells containing them occur in discontinuous rows. Furthermore, the neighbouring cells in *F. sumatrana* are said to be 10-11 in number but our materials show only 6-8 cells.

The shoot apical organization in *Freycinetia rigidifolia* and *Pandanus tectorius* clearly indicate two contrasting patterns in that the one presented by *F. rigidifolia* seems to be different from that of *Pandanus tectorius* in having three distinct zones namely 2 layered distinct tunica, central mother-cell zone and cambium-like zone while that of *P. tectorius* is characterized by only two distinct zones such as mantle layers and central mother-cell zone (cf. Pl. 3, A; 5, A), although the existence of a central mother-cell zone is shared by these two taxa. Between these two taxa *F. rigidifolia* appears to be unique in having a well stabilized 2-layered tunica and a 5-6-layered cambium-like zone (Pl. 3, A) whereas in *P. tectorius* there are only mantle layers which are so designated on account of their fluctuating condition with regard to their number and patterns of cell division. Furthermore, the shoot apex in *F. rigidifolia* is much bigger than in *P. tectorius*.

Thus it is interesting to note that as far as the organization of the shoot apex in *P. tectorius* is concerned, it appears to stand in contrast to and different from that of *F. rigidifolia* in regard to the absence of a cambium-like zone, development of mantle layers and narrower apex. On the other hand, in terms of development and the activity of primary thickening meristem, it may be pointed out that in *F. rigidifolia* it is not as distinct as it is in *P. tectorius*. Thus it may be concluded that the shoot apex organization in *F. rigidifolia* portrays one particular pattern despite its sharing certain common features with *P. tectorius* while the latter represents totally a different picture. It may be presumed that a comparative study of shoot apices in adequate number of taxa representing all the sections may block out at least certain major patterns of organization which could also find some applications in taxonomic considerations as demonstrated by the taxa investigated here.

In the shoot apex of *F. sumatrana* although not studied in detail for want of enough materials it is worthwhile to record the presence of ergastic substances in the form of spindle-shaped raphide sacs and the cubical crystals, particularly the latter surrounding the procambium and provascular tissues and this particular feature is quite characteristically common in the median region of the shoot apex but in the case of *F. rigidifolia* and *P. tectorius* only raphide sacs are observed and that too in the peripheral parts of the shoot apex. Histochemical features of this kind (type of ergastic substances, relative frequency and pattern of distribution etc.) if collected out of shoot apical studies may not go without showing any taxonomic import.

CONCLUSION

The comparative anatomical study of two species of *Freycinetia* (*F. rigidifolia* and *F. sumatrana*) endemic to Andamans indicate interspecific differences of sufficient magnitude which are observed with respect to type and degree of specialization of the stomata, number of neighbouring cells, shape of keel, structure of marginal spines, number of hypodermal layers in the leaf, presence or absence of hypodermis in the sheaths and of silica-bodies, nature of bundle sheath, number of layers in circumvascular sclerenchyma, number of bulliform cells and their respective number of layers, size, shape and pattern of distribution of sclerenchyma strands, presence or absence of raphide sacs, number of assimilatory tissues and their continuity or discontinuity, number of cell layers in the air-cavities, presence or absence of translucent layer of parenchyma in the adaxial subepidermal part of the midrib and presence or absence of cortical silica-bearing idioblast in the stem. Likewise the structure and organization of the shoot apices of *Freycinetia rigidifolia* and *Pandanus tectorius* exemplify two contrasting models in that the former is characterized by 3 distinct zones (2-layered tunica, central mother-cell zone and cambium-like zone) while the latter 2 zones only (mantle layers and central mother-

cell zone). The significance of several anatomical characters of different organs including those of shoot apices and the necessity of further systematic anatomical investigations of all the taxa for the sake of taxonomic considerations have been discussed and emphasized.

KEY TO FIGURE LETTERING AND TEXT ABBREVIATIONS

AB., abaxial epidermis	O.L., outer ledge
A.C., air-cavity	P., papillae
AD., adaxial epidermis	PC., procambium
A.T., assimilating tissue	P.C., parenchymatous cortex
B.C., bulliform cells	PH., metaphloem
ca., circa	PL., phelloid layer
CA., secretory cavity	P.X., protoxylem
C.C., companion cell	R., raphide
CHL., chlorenchyma	R.S., raphide sac
C.M., central mother-cells	S., sclerenchyma
CR., crystal	S.B., silica-body
C.Z., cambium-like zone	S.C., subsidiary cell
CU., cuticle	SH., bundle sheath
C.V.S., circumvascular sclerenchyma	S.P., silica particle
D., silica deposit	S.S., sclerenchyma strands
EN., endodermis	S.T., sieve tube element
EX., exodermis	ST.C., stomatal chamber
F.B., fiber bundle	S.Z., shell zone
G.C., guar cell	T., tunica
HY., hypdodermis	T.M., thickening meristem
L.B., leaf trace bundle	T.P., translucent parenchyma
L.P., lobed parenchyma	TY., tylose
M., mantle	V.B., vascular bundle
O.B., opaque body	XY. or M.V., metaxylem vessel

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